Mechanisms and machines

5^{th} Semester, Mechanical Engineering

Short Questions with Answer

Module 3

Q: Write down the components of a vibrating system.

A: The basic components of a vibrating system include:
- Inertia mass (m).
- Restoring element or stiffness (K).
- Damping element (C).

Q: What are the types of vibration?

A: the types of vibration are basically classified into 4 categories:
- Based on nature of excitation
  - Free vibration
  - Forced vibration
- Based on damper
  - Undamped vibration
  - Damped vibration
- Based on D.O.F.
  - Single D.O.F. vibration
  - Multiple D.O.F. vibration
- Based on orientation of vibration
  - Longitudinal vibration
  - Transverse vibration
  - Torsional vibration

Q: Write the difference between free & forced vibration.

A: The difference between free and forced vibration are as follows:
- **Free vibration:** After giving initial disturbance, if the system is left to vibrate on its own without external forces or friction, then it is called free vibration.

- **Forced vibration:** If in a system, a repeated force acts continuously, the vibration is said to be forced vibration.

Q: What is torsional vibration?

A: Torsional vibration is a type of mechanical vibration that occurs when the twisting motion of a rotating shaft is not uniform. It is caused by changes in the torque applied to the shaft, such as the presence of an eccentric component.

Q: What is transverse vibration?

A: Transverse vibration is defined as the type of vibration where the displacement of the body is perpendicular to the propagation of vibrational energy.

Q: Describe:
- Magnification factor.
- Isolation factor.
- Transmissibility ratio.
- Damping factor
- Critical damping.

A: The description of the following terms are as follows:
- **Magnification factor:** It's defined as the ratio of the dynamic amplitude to the static deflection under the action of the force (F_0).

  $$\mathbf{D = (Dynamic\ Amplitude)/(Static\ Deflection)}$$

- **Isolation factor:** Also called transmissibility ratio, is defined as the ratio of transmitted force to the applied force.

  $$\boldsymbol{\varepsilon = (F_t)/(F)}$$

- **Damping factor:** Also called damping ratio, is defined as the ratio of normal damping to critical damping.

  $$\boldsymbol{\therefore\ \rho = C/C_C}$$

- **Critical damping:** Critical damping is defined as the minimum amount of damping required to stop a vibrating system as quickly as possible without overshooting the final steady state.

  $$\boldsymbol{\therefore\ C = C_C}$$

Q: Write the condition for resonant vibration.

A: When the frequency of forced vibration becomes equal to the frequency of free vibration, the condition is called resonance vibration.

$$\boldsymbol{\therefore\ r = \omega/\omega_n = \omega_n/\omega_n = 1}$$

Q: What is balancing, & what are its significance.

A: Balancing is defined as the process of designing or modifying the machine such that the unbalancing is reduced to a proper level & if possible, is eliminated entirely.

The significance of balancing is:
- To reduce vibration and stress on the components.
- Improve the machine performance.
- Increase the lifespan of the machinery.

Q: Write the conditions for static and dynamic balancing.

A: The conditions for static and dynamic balancing are:
- For static balancing, the net dynamic force acting on the shaft is zero i.e. $F_c=0$.
- For dynamic balancing, the dynamic forces will be zero and the sum of moments about any point in the plane must be zero.

Q: What is hammer blow?

A: The maximum magnitude of unbalanced force acting in perpendicular direction to the line of stroke is called hammer blow.

Module 2

Q: What is the function of a gyroscope?

A: The function of a gyroscope is to resist any change in the rotor axis.

Q: What is a gyroscopic couple? Derive a formula for its magnitude.

A: Gyroscopic couple is defined as a type of reaction couple that develops due to the change of axis from any disturbances.

$$\boxed{\therefore\ \mathbf{C = I\omega\omega_p}}$$

Q: What is an overturning couple?

A: Overturning couple is defined as the product of centrifugal force acting on the C.O.M of a body and the perpendicular distance i.e. height of the C.O.M of the body from the ground.

$$\boxed{\therefore\ \mathbf{C_o = F_c h}}$$

Q: What is a governor, and how does it function to control the speed of an engine or machine?

A: A governor is a mechanism that senses changes in the speed of an engine or machine and adjusts the input to maintain a constant speed. It typically uses centrifugal force to control the position of a throttle or valve.

Q: What is governor sensitivity?

A: A governor is said to be sensitive when it readily response to a small change in speed.

$$\textbf{Sensitivity} = (N_2\text{-}N_1)/N$$

Q: What is governor stability?

A: Governor stability refers to the ability of the governor to maintain a constant speed in the face of external disturbances, such as changes in load or power input. It is important for ensuring smooth and consistent operation of an engine or machine.

Q: What is governor hunting, and what are the key factors that contribute to it?

A: Governor hunting refers to the tendency of a governor to oscillate around its set points rather than settling at a steady speed. It can be caused by factors such as friction, inertia, and non-linearity in the governor mechanism.

Q: What is the governor's effort?

A: The mean force exerted on the sleeve during a given change in speed is known as governor effort.

$$P = C[m+M]g$$

Q: What is governor power?

A: Governor power is defined as the work done at the sleeve for a given percentage change of speed.

$$\textbf{Governor Power} = Px$$

Q: What is isochronism?

A: A governor is said to be isochronous if the equilibrium speed is constant for all radii of rotations. Such governors are not practical.

Module 1

Q: What are the two types of lower pairs in mechanisms, and how do they differ?

A: The two types of lower pairs in mechanisms are revolute pairs and prismatic pairs. Revolute pairs allow relative rotation between two links, while prismatic pairs allow relative sliding motion.

Q: Explain the principles of operation of the Davis Steering Gear and the Ackermann Steering Gear.

A: The Davis Steering Gear uses a worm and sector mechanism to convert the rotary motion of the steering wheel into linear motion that steers the vehicle's wheels. The Ackermann Steering Gear uses a complex linkage mechanism to ensure that the vehicle's wheels turn at different angles when cornering.

Q: What is a Hooke's joint, and how is it used in mechanical systems?

A: A Hooke's joint is a type of universal joint that allows two rotating shafts to be connected at an angle. It is commonly used in drive shafts and other mechanical systems that require flexible coupling.

Q: What is a cam, and how is it used in machinery?

A: A cam is a mechanical component that is used to convert rotary motion into reciprocating or oscillating motion. It typically consists of a rotating disc or cylinder with a shaped profile that interacts with a follower to produce the desired motion.

Q: What is the fundamental law of cam design, and how is it used in cam analysis?

A: The fundamental law of cam design states that the motion of the follower must be smooth and continuous. It is used in cam analysis to ensure that the cam profile meets the desired motion requirements.

Q: What are the three main types of cam profiles, and how do they differ?

A: The three main types of cam profiles are simple harmonic, uniform velocity, and constant acceleration and retardation. They differ in the shape of the cam profile and the resulting motion of the follower.

Q: How are cam profiles generated by graphical methods, and what are some common techniques?

A: Cam profiles can be generated by graphical methods using techniques such as the tangent method, the circular arc method, and the trial-and-error method. These methods involve drawing the desired motion curve and then constructing the cam profile that produces that motion.

Q: What is a turning moment diagram, and how is it used in the design of flywheels?

A: A turning moment diagram shows the variation of torque over one or more cycles of operation for a rotating machine. It is used in the design of flywheels to determine the required mass and distribution of the flywheel to ensure smooth operation and minimize energy fluctuations.

Q: What is the purpose of a flywheel in a mechanical system, and how does it work?

A: A flywheel is a rotating mass that stores energy and helps to smooth out fluctuations in torque and speed in a mechanical system. It works by converting excess energy into rotational kinetic energy, which can be released as needed to maintain a more constant output.

Q: How is the size of a flywheel determined from a turning moment diagram, and what factors affect the design?

A: The size of a flywheel is determined by analyzing the turning moment diagram to determine the required energy storage capacity and rotational speed. The design is also affected by factors such as the type of engine or machine, the desired operating conditions, and the available space and weight constraints.

Probable Questions:-

Mechanisms and Machines

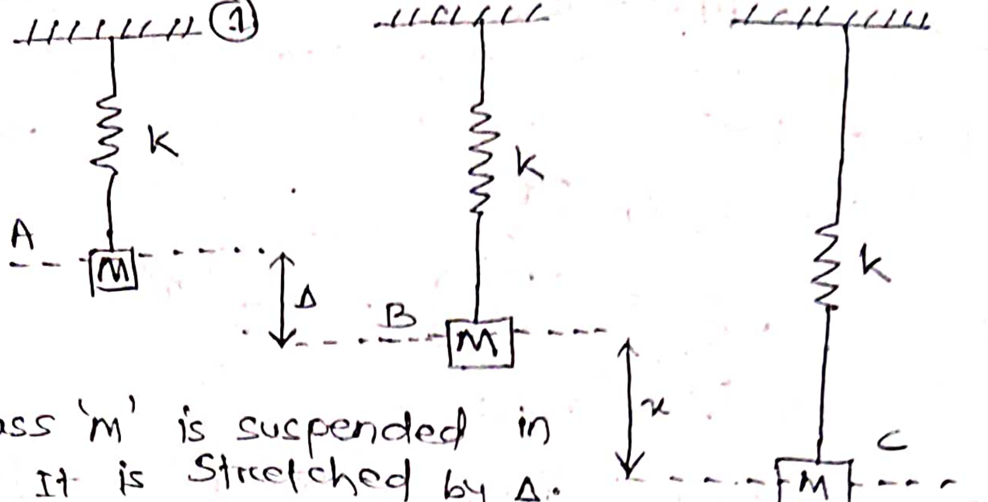
5^{th} sem.

MODULE-3

[6×10]

1/ Define Equilibrium method for longitudinal vibration.

Ans.



→ If a mass 'm' is suspended in a spring. It is stretched by Δ.

so in static equilibrium, upward force is equal to downward force.

mg

So, $K\Delta = mg$ —— ①

If the mass (M) is pulled further down through a distance 'x', the force acting on the mass will be,

$$m\ddot{x} + k(x+\Delta) - mg = 0$$

$$\Rightarrow m\ddot{x} + kx + \cancel{k\Delta} - \cancel{mg} = 0$$

$$\Rightarrow \boxed{m\ddot{x} + kx = 0} \quad —— ②$$

so, $\ddot{x} + \frac{k}{m}x = 0$

$\Rightarrow \ddot{x} + \omega_n^2 x = 0$ $\quad \Rightarrow \boxed{\omega_n = \sqrt{\frac{k}{m}}}$

(This is undamped natural frequency)

→ It's unit is rad/sec.

• Time period (T) $= \frac{2\pi}{\omega_n} = 2\pi\sqrt{\frac{k}{m}}$

→ Undamped linear natural frequency,

$$\boxed{f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}} \text{ Hz}$$

2/ Explain logarithmic decrement.

Ans Basically logarithmic decrement is the finding the amount of damping in the system.

→ It measures the rate of decay of free oscillations.

→ We can also say, it is the natural logarithm of the ratio of any two sucessive amplitudes.

$$\delta = \ln\left(\frac{x_1}{x_2}\right)$$

$$\Rightarrow \delta = \ln\left(\frac{x_n}{x_{n+1}}\right) = \ln e^{\xi \omega_n T_d}$$

So, $\boxed{\delta = \xi \omega_n . T_d}$

• Substituting for damped period,

$$T_d = \frac{2\pi}{\omega_n \sqrt{1-\xi^2}}$$

$$\delta = \xi \omega_n \frac{2\pi}{\omega_n \sqrt{1-\xi^2}}$$

$$\Rightarrow \boxed{\delta = \frac{2\pi\xi}{\sqrt{1-\xi^2}}}$$

→ For small damping, $\sqrt{1-\xi^2} \simeq 1$ & $\delta = 2\pi\xi$.

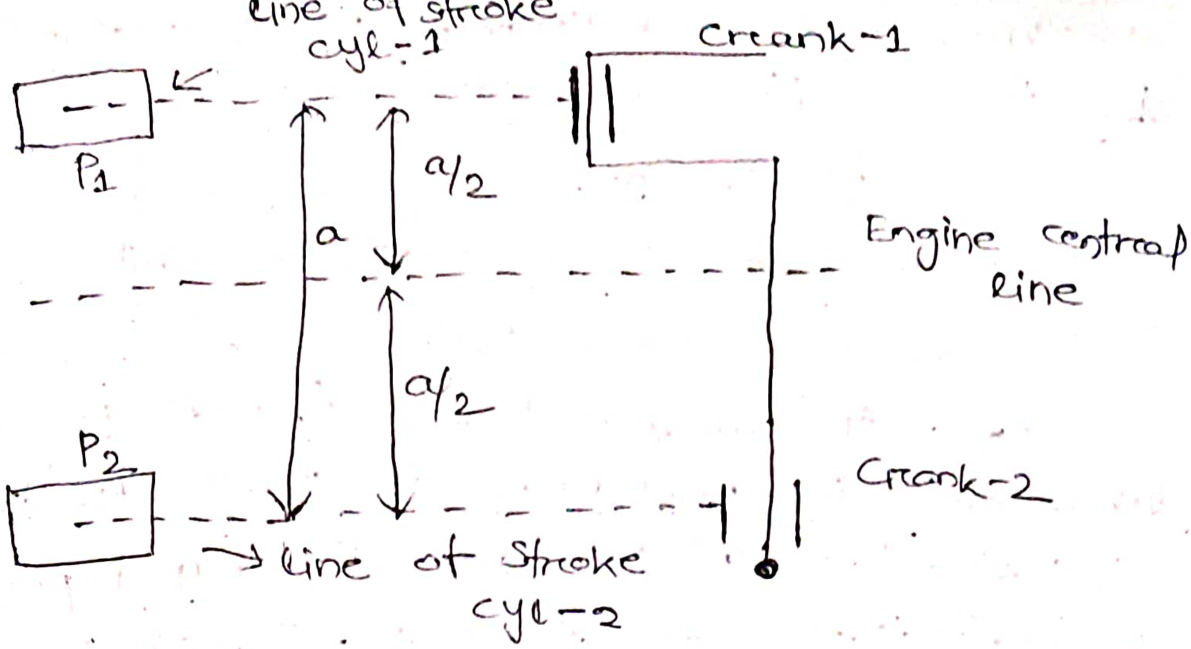
3/ What is swaying couple drive?

Ans:- The unbalanced parts of the primary unbalanced force along the line of stroke stroke for the 2 cylinders constitute a horizontal couple about the engine central line. This is known as swaying couple.

→ This tends to make the leading wheel sway from side to side.

Let 'a' be the distance bet^n 2 centre line of two cylinders.

* Taking moment about engine centre line is swaying couple.



So, $(1-c)\,m\omega^2 r\cos\theta \times \frac{a}{2} - (1-c)\,m\omega^2 r\cos(90^\circ+\theta) \times a/2$

$= (1-c)\,m\omega^2 r\left(\frac{a}{2}\right)(\cos\theta + \sin\theta)$

- swaying couple is $\min^m$ or $\max^m$ when,

$\Rightarrow \frac{d}{d\theta}(\cos\theta + \sin\theta) = 0$

$\Rightarrow -\sin\theta + \cos\theta = 0$

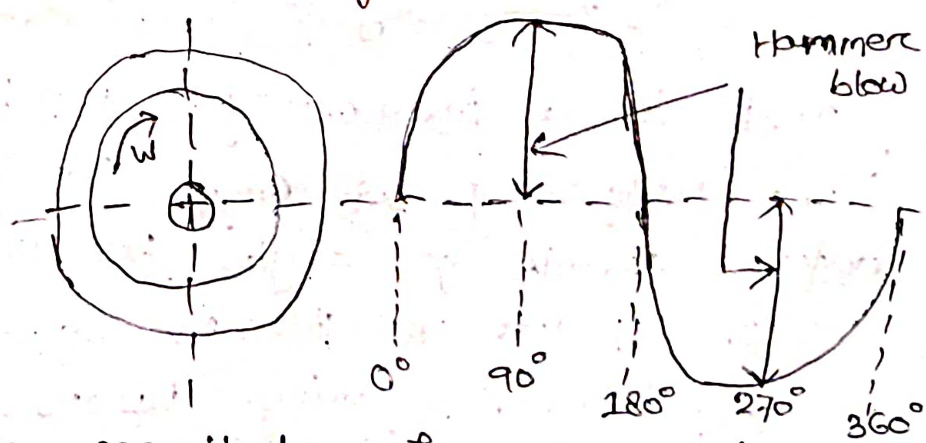
$\Rightarrow \tan\theta = -1$, $\theta = 45^\circ$ or 225°

Now, $(1-c)\,m\omega^2 r\left(\frac{a}{2}\right)(\cos 45^\circ + \sin 45^\circ)$

$$\boxed{\therefore \text{swaying couple} = \pm \frac{a}{\sqrt{2}}\, m\omega^2 r}$$

4/ what do you mean by hammer blow drive? Explain with a neat diagram.

Ans



→ The maximum magnitude of unbalanced force along the perpendicular to line of stroke is known as hammer blow.

We know that unbalanced force along the ⊥r to the line of stroke is equal to,

$$Bb\omega^2 \sin\theta.$$

It is maximum when, $\theta = 90°$ or $270°$

$$\text{Hammer blow} = Bb\omega^2$$

Due to hammer blow there is a vibration in pressure in bet^n the wheel & rail. Let 'p' be the downward pressure ~~in bet^n the wheel~~ of rail. So net pressure bet^n wheel & rail is, $P \pm Bb\omega^2$.

If it is -ve then wheel will be lifted from rail, so the limiting condition in order that wheel does not leave from rail is given by, $\boxed{p = Bb\omega^2}$

& permissible value of angular speed,

$$\boxed{\omega = \sqrt{\frac{p}{Bb}}}$$

5/ Explain the secondary balance of multi cylinder inline engine?

Ans We know, secondary force,

$$F_s = \frac{m\omega^2 r \cos 2\theta}{n} = m(2\omega)^2\left(\frac{r}{4n}\right)\cos 2\theta$$

That is a imaginary crank of length '$r/4n$' revolving at twice the speed of the actual crank & angle be '2θ'.

In order to give the secondary balance of the reciprocating parts of a multicylinder engine following 2 conditions must be satisfied.

(a) The algebraic sum of secondary forces is zero & the forces polygon is closed.

$$\boxed{\Sigma m (2\omega^2)\left(\frac{r}{4n}\right) \cos 2\theta = 0}$$

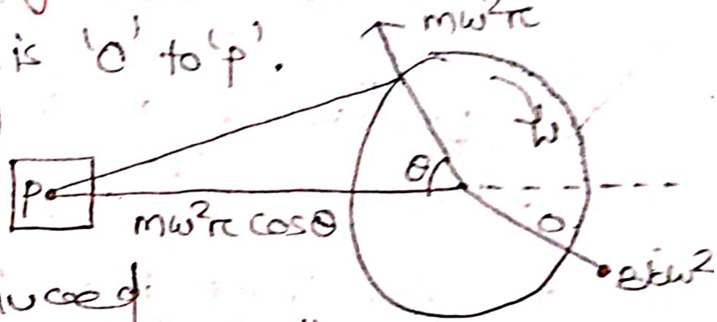
(b) The algebraic sum of couples about any point in the plane of secondary forces must be zero & the couple polygon is closed.

$$\boxed{\Sigma m(2\omega^2)\left(\frac{r}{4n}\right) a \cos 2\theta = 0}$$

6/ With a neat diagram, explain briefly the ~~partie~~ partial primary balance method.

Ans The dir^n of 'F_p' is 'O' to 'P'.

It may be considered as the component of centrifugal force produced by the rotating mass 'm' at the crank radius



Hence a balanced mass must be apply to balance this 'F_p'.

Let us consider a mass 'B' be placed diametrically opposite to the crank at a radius of 'b'.

→It has 2 components. (i) $Bb\omega^2 \cos\theta$
(ii) $Bb\omega^2 \sin\theta$

The primary force is balanced if.

$$m\omega^2 r = Bb\omega^2 \Rightarrow \boxed{mr = Bb}$$

Hence another unbalanced force is introduces i.e. $Bb\omega^2 \sin\theta$. In order to avoid this let a fraction 'c' of the reciprocating masses is balanced. so, $\boxed{cmr = Bb}$

& the value of 'c' varies from, $\frac{2}{5}$ to $\frac{4}{5}$.

$c = \frac{2}{3}$ (for locomotives)

→ so unbalanced force along the line of stroke is given by,

$$rm\omega^2 \cos\theta - Bb\omega^2 \cos\theta$$

$$= m\omega^2 r \cos\theta - cmr\omega^2 \cos\theta$$

$$= m\omega^2 r \cos\theta (1-c)$$

unbalanced force along the tr line will be given by; $Bb\omega^2 \sin\theta$

$$= cmr\omega^2 \sin\theta$$

so, resultant unbalanced force is given by,

$$R = \sqrt{(1-c)\, m\omega^2 r \cos\theta + (cmr\omega^2 \sin\theta)^2}$$

$$= m\omega^2 r \sqrt{(1-c)^2 \cos^2\theta + c^2 \sin^2\theta}$$

If the balancing mass is required the revolving masses & also partially balance the reciprocating masses, then

$$Bb = Mr + cmr$$

$$= (M + cm)\, r$$

where, M = magnitude of revolving mass

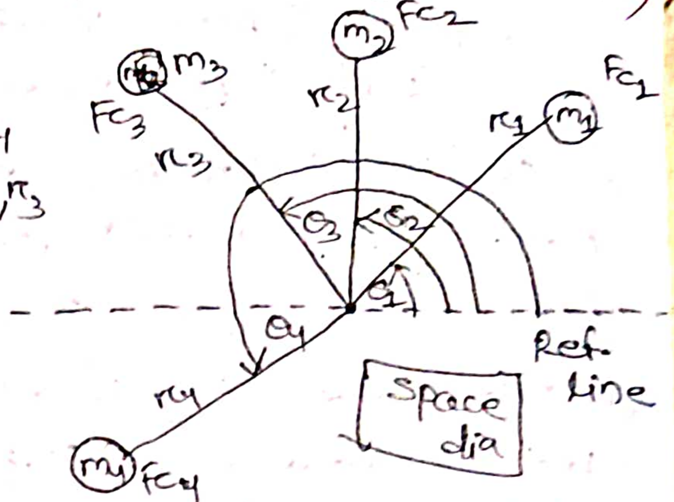
m = magnitude of reciprocating mass

& r = Radius of Crank.

(M + cm) = Total equivalent mass at the crank radius which must be balanced.

7/ Explain the balancing of several masses rotating in the same plane. (Analytical method)

Ans. consider 4 masses of magnitude m_1, m_2, m_3 & m_4 at a distance of r_1, r_2, r_3 & r_4 from the axis of rotation.



→ Let $\theta_1, \theta_2, \theta_3$ & θ_4 be the angles of these masses with the horizontal reference line.

Let the angular velocity be ω rad/sec.

→ The magnitude & postion of balancing mass may be found out by analytical method.

- Analytical metod:-

step-1
Find the centrifugal forces in 'mr' form.

step-2
Resolve the centrifugal forces horizontally & vertically.

$$\Sigma_H = F_{c1}\cos\theta_1 + F_{c2}\cos\theta_2 + \cdots$$

$$\Sigma_V = F_{c1}\sin\theta_1 + F_{c2}\sin\theta_2 + \cdots$$

step-3 Find the magnitude of resultant of centrifugal forces by,

$$F_c = \sqrt{(\Sigma_H)^2 + (\Sigma_V)^2}$$

Step-4 If 'θ' be the angle of resultant force 'F_c', then $\tan\theta = \frac{\Sigma V}{\Sigma H}$.

step-5 The balancing force is equal to the resultant force but in opposite dirn.

So, $F_c = mr$.

8/ What are the possibilities occurs (in balancing of single rotating mass in diff. planes? Also write the conditions for static & dynamic balancing.

Ans In the balancing of a single rotating mass by 2 masses rotating in different planes, there are 2 possibilities.

(a) The plane of disturbing mass may be in betⁿ 2 balancing plates.

(b) The plane of disturbing mass may be lie on the left or right of the two planes, containing the balancing masses.

- Condition for static balancing :-

The net dynamic force acting on shaft is zero.

$$\Rightarrow \boxed{F_c = 0}$$

- Condition for dynamic balancing :-

The sum of dynamic forces will be zero & the sum of moments about any point in the plane must be zero.

So, $\boxed{\begin{array}{l} F_c = 0 \\ M_A = 0 \end{array}}$

9/ What do you mean by balancing of locomotives? Give an idea bout coupled & un-coupled locomotive?

Ans Locomotives usually have 2 cylinders.

→ If the cylinders are mounted betⁿ the wheels it is called inside cylinder locomotives.

→ If the cylinders are mounted outside the wheel it is called outside cylinder locomotives.

→ The crank of 2 cylinders are set at 90° to each other.

Balanced masses are placed on wheels in both types. In other way locomotives are can be divided into 2 types.

→ coupled locomotives
→ un-coupled locomotives.

• In a <u>coupled locomotives</u>, the driving wheels are connected to leading & training wheel by an outside coupling rod which connects the crank pin of the wheel. There are six planes for consideration. 2 cylinders, 2 wheels & 2 of the coupling rod.

• In a <u>un-coupled locomotive</u>, the effort is transmitted to one pair of wheels. There are 4 planes for consideration. 2 for cylinder & 2 for wheels.

10/ What is forced vibration? Write the expression for violent vibration & condition for resonance.

Ans <u>Forced vibration</u>:-

It is the situation when an alternating force or motion is applied to a mechanical system.

→ It basically occurs when motion is sustained or driven by an applied periodic force in either damped or undamped systems.

E.o.m. → $\boxed{m\ddot{x} + c\dot{x} + kx = f_0 \sin\omega t}$

The general sol^n is given by,

C.F. + P.I.
(Complementary function) (Particular Integral)

If the R.H.S. of the E.o.m. is 'zero' then the sol^n is called Complementary function.

$$\boxed{C.F. = e^{-\xi \omega_n t} \sin(\omega_t t - \phi)}$$

$W_n = \sqrt{k/m}$, $W_d = W_n \sqrt{1 - p^2}$

ω = Excited frequency

If $\boxed{W = W_n}$, then the condition is called violent vibration,

Excited frequency = Natural frequency

- <u>Condition</u> for <u>resonance</u> :-

When frequency of post vibration is equal to frequency of pre-vibration then the condition is called resonance.

$\omega = \omega_n$

$$\boxed{r = \frac{\omega}{\omega_n} = 1}$$

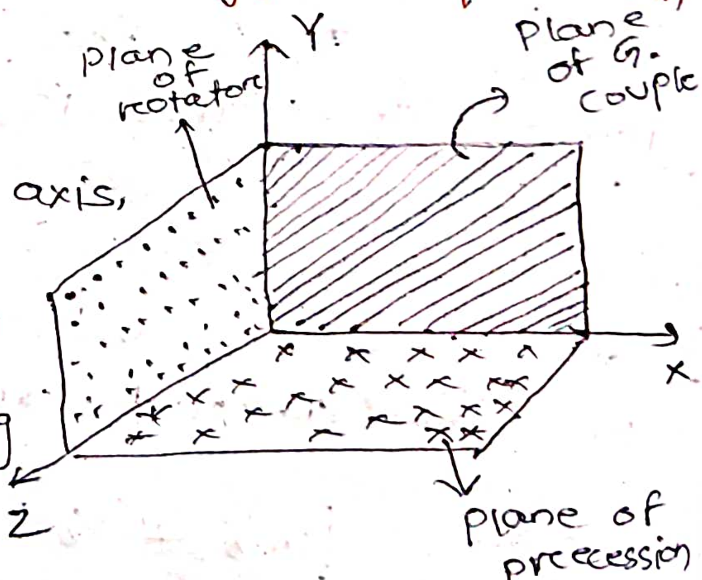
→ Resonance amplitude.

$$\boxed{X = \frac{F_0}{k} \cdot \frac{1}{2\xi}}$$

MODULE – 2

[6 x 10]

1/ Define Plane and axis of gyroscope with neat sketch.



<u>Ans</u> If a disc is rotated about its axis, this is called spinning axis.

→ Due to some disturbing forces it may be changes it's direction.

→ The changed axis is known as precession axis. The plane of spin is perpendicular to axis of spin & plane of precession is perpendicular to precession axis.

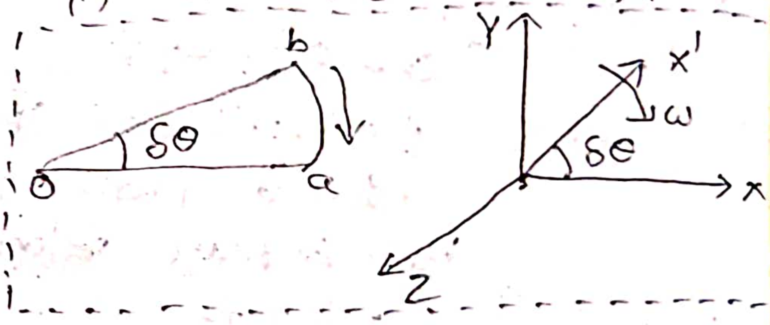
Axis	
Axis	X-axis = Axis of rotation
	Y-axis = Axis of precesion
	Z-axis = Axis of gyroscopic couple

- Every plane is normal to other two planes.

Q/ What do you mean by Gyroscopic couple? Explain briefly.

Ans: In a gyroscope, the reaction couple devlop due to change of axis for any disturbances.

→ consider a disc of mass M.O.I. 'I' which is spinning with angular speed 'ω' along the axis of spin 'ox' in clockwise direction.



→ The angular momentum = $I\omega$ & it's represented by 'oa'. Let after 'δt' axis of precesion occupies 'ox'' making an angle 'Δθ' with its initial position.

The angular momentum represented by 'ob'. The change in angular momentum indicated by 'ab'.

→ The change in angular momentum takes plane due to couple. The couple is equal to the rate of change of angular momentum.

$$\boxed{C = I\omega \frac{d\theta}{dt}}$$

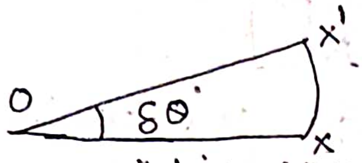
$\frac{d\theta}{dt} = \omega_p$ = Angular speed of precesion

so, Gr. couple, $\boxed{C = I\omega\omega_p}$ or

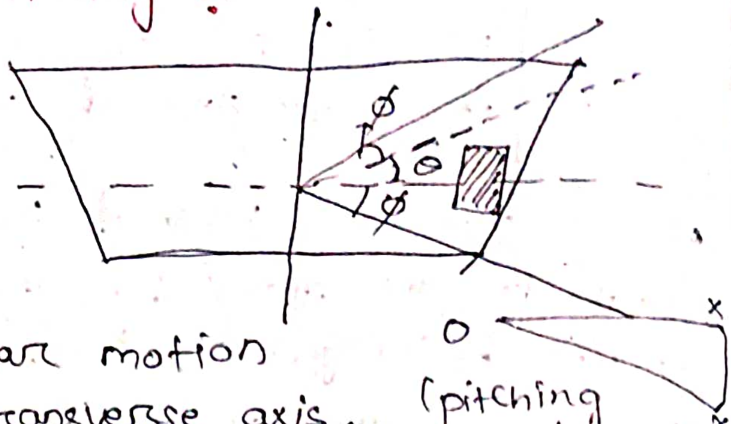
$$\boxed{\begin{gathered} C = mgl \\ F = C/x \\ \omega = \frac{2\pi N}{60} \end{gathered}}$$

3/ What are the effects of gyroscopic couple on a ship during pitching ?

Ans



(pitching upward)



(pitching downward)

→ If the limited angular motion of ship about the transverse axis.

→ In pitching, the motion of axis of spin about transverse axis is simple harmonic.

→ Angular displacement of the axis of spin from ~~the~~ mean positions after 't' seconds is given by,

$$\theta = \phi \sin \omega_1 t$$

where, ϕ = Amplitude of spin i.e. max^m angle turns from mean position in rad.

ω_1 = Angular velocity of SHM

$= 2\pi / t_p$

where, 't_p' is the time period of SHM in sec.

Angular velocity of precession is,

$$\omega_p = \frac{d\theta}{dt} = \frac{d}{dt}(\phi \sin \omega_1 t)$$

$$= \phi \omega_1 \cos \omega_1 t$$

$$(\omega_p)_{max} = \phi \omega_1 \quad (\cos \omega_1 t = 1)$$

$$\omega_1 = 2\pi / t_p \text{ rad/sec.}$$

Let, I = M.O.I. of rotor in kgm^2

ω = Angular velocity of rotor in rad/sec.

So, max^m gyroscopic couple $\boxed{(C) = I\omega(\omega_p)_{max}}$

• Effects :-

① Upward → Try to move towards starboard (R.H.S)

② Downward → Try to move towards port (L.H.S.)

Angular accel^n during pitching can be given by,

$$\alpha = \frac{d^2\theta}{dt^2} = -\phi \omega_1^2 \sin \omega_1 t$$

$$\boxed{\alpha_{max} = -\phi \omega_1^2}$$

4/ The rotor of the turbine of a ship has a mass of 2500 kg & rotates at a speed of 3200 rpm ccw when viewed from stern. The rotor has $k = 0.4$ m. Determine the gyroscopic couple & its effect when :-

(a) The ship steers to the left in a curve of 80 m radius at a speed of 15 knots. Write the effect. (1 knot = 1.860 kmph)

Ans: Given, $m = 2500$ kg,

$N = 3200$ rpm

$\omega = 335.1$ rad s^{-1}

$k = 0.4$ m

so, $I = mk^2 = 400$ kg m^2

(a) $V = 15$ knots

$= 7.75\ ms^{-1}$

& $r = 80$ m

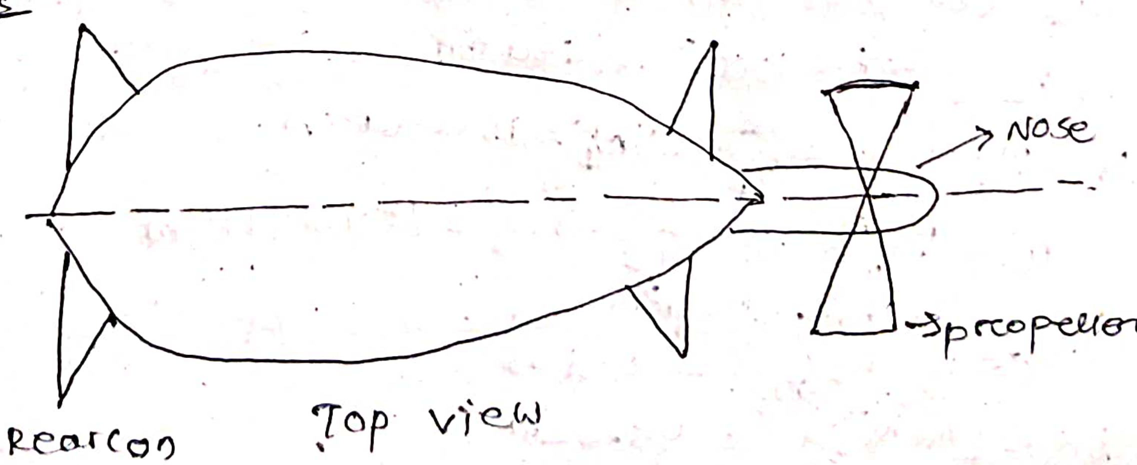
$\therefore \omega_p = \frac{V}{r} = 0.096875$ rad/sec

$\therefore C = I\omega\omega_p = 12,985.125$ Nm.

$\therefore$ Effect → lower the bow, raise the stern.

5/ Write the effect of gyroscopic couple on an aeroplane/aircraft ? (Diagram required)

Ans



Top view

→ In aeroplanes, gyros are used in attitude, compass & turn co-ordinators. These instruments

contain a wheel or rotor rotating at a high RPM which gives it two important properties.

(a) Rigidity

(b) precession

→ construction wise the gyro fixed in the instrument by rings or gimbals & these give the gyro certain motions of freedom It is these motions or movement in each plate which allow for certain characteristics used in these instruments.

Q/ A porter governor has equal arms, each 250 mm long & pivoted on the rotation axis, Each ball has a mass of 5 kg & central load mass = 25 kg on the sleeve. The rotation radius of the ball is 150 mm when the governor belongs to lift & 200 mm when the governor is at max^n speed. Find the speed range, sleeve lift, governor effort & governor power, when frictional force is neglected.

Ans Given, arm length = 250 mm

$m = 5\,kg$

$M = 25\,kg$

$r_1 = 150$ mm

$r_2 = 200$ mm

$\therefore h_1 = \sqrt{(250)^2 - (150)^2} = 200$ mm

& $h_2 = \sqrt{(250)^2 - (200)^2} = 150$ mm

$N_1 = \frac{m+M}{m} \times \frac{895}{h_1} \Rightarrow N_1 = 163.86$ rpm

$N_2^2 = \frac{m+M}{m} \times \frac{895}{h_2} \Rightarrow N_2 = 189.21$ rpm

$x = 2(h_1 - h_2) = 100$ mm

$c = N_2 - N_1 / N_1 = 0.155$

$P = c\,[m+M]\,g = 45.62\,N$

$N_R = N_2 - N_1 = 25.35$ rpm

P_x = power $= 4.562$ Nm.

7/ Calculate the vertical height of the watt governor when it rotates at 60 rpm. Also, find the change in vertical height when its speed increases to 61 rpm.

Sol^n Given, $N_1 = 60$ rpm
& $N_2 = 61$ rpm.

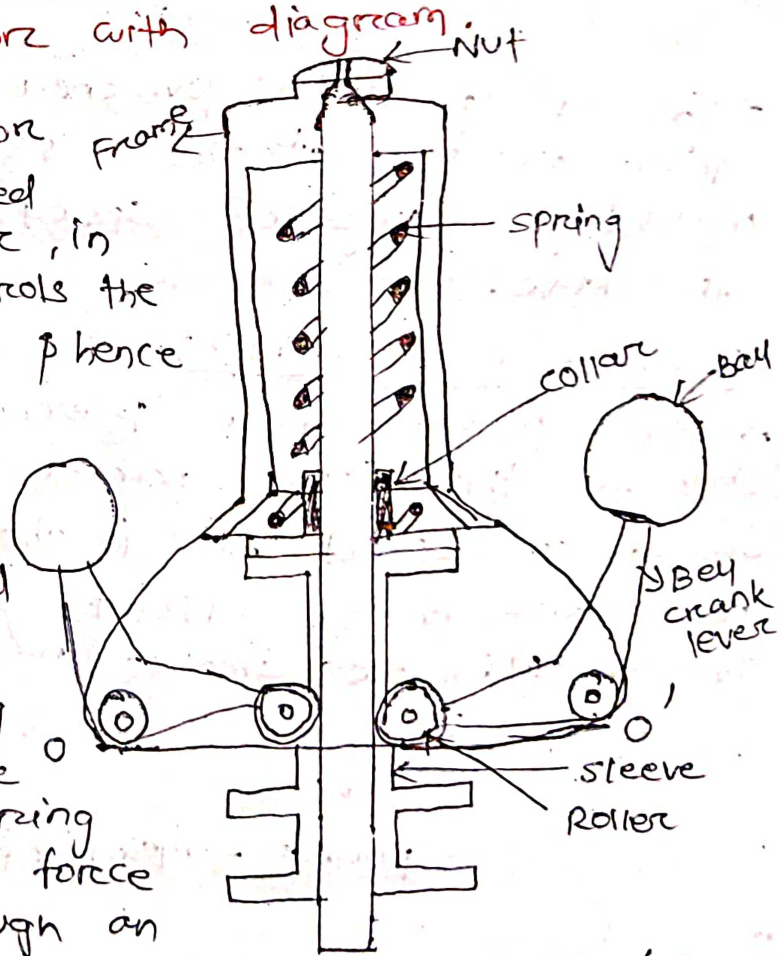
$$\therefore h_1 = \frac{895}{N_1^2} = \frac{895}{60^2} = 0.2486\,m$$

$$\therefore h_2 = \frac{895}{N_2^2} = \frac{895}{61^2} = 0.2405\,m$$

$$\therefore h = h_1 - h_2 = 0.2486 - 0.2405$$
$$= 0.0081\,m$$
$$= 0.0081 \times 10^3 \times 10^{-3}\,m$$
$$= 8.1\,mm$$

8/ Describe the construction & working of a Hartnell governor with diagram.

Ans Heartnell governor is a spring controlled centrifugal governor, in which a spring controls the movement of the ball & hence the sleeve.



→ It consists of a frame, in which a precompressed helical spring is housed.

→ The casing & spring can rotate about the spindle axis. The spring applies a downward force on the sleeve through an adjustable collar. The spring force can be adjusted by a nut provided. Two bell crank levers are pivoted at O, O' to the frame, each carrying a ball at one end a roller at another end.

The roller fits into the grooves of the sleeve. The sleeve moves up and down depending on the governor speed. When the speed of governor increases, the ball tends to fly outward from the axis of governor, but balls movement is constrained. The bell crank lever moves on pivot, roller end of lever lifts the sleeve upward against the spring force. This movement transferred to the throttle valve through the suitable mechanism, the result is a low fuel supply & decreasing speed.

Q/ What do you mean by governor effort and power? What is the formula to calculate?

Ans:

Effort of a governor:-

→ The effort of a governor is the mean force exerted at the sleeve for a given percentage change of speed or lift of the sleeve.

Power of a Governor:-

→ The power of a governor is the work done at the sleeve for a given percentage change of speed. It is the product of the mean value of the effort & the distance through which the sleeve moves.

Mathematically,

power = mean effort × lift of sleeve

10/ what are the difference between governor & flywheel ?

Ans:- The difference bet^n governor & flywheel are as follows.

Flywheel	Governor
→ It's function is to control the speed variations caused by fluctuations of engine turning moment during a cycle.	→ It's function is to regulate the mean speed of a engine within prescribed limit when there are variations of load.
→ mathematically it controls by δN/δt.	→ mathematically it controls by δN.
→ Flywheel acts as a reservoir, it stores energy due to its mass moment of inertia & releases energy when required.	→ A Governor regulates the speed by regulating the quantity of charge/working fluid of prime mover.
→ It regulates speed in one cycle only.	→ It regulates speed over a period of cycle.
→ Flywheel has no control over supply of fluid/charge.	→ Governor takes care of quantity of fluid.

MODULE - 1

[6×10]

1/ Write short note on cam & follower with types and mechanisms.

Ans CAM:-

→ A cam is a rotating element that gives oscillating or reciprocating motion to the follower which is another element of this machine by direct contact.

This part is mainly used to transform the motion from rotary into linear to another part. It is a part of a machine which can be a rotating wheel (an electric wheel) or a shaft that strikes a lever's various points at its circular path.

→ Types of cam :-

- Disk or Plate cam
- Cylindrical cam
- Translating cam
- Wedge cam
- Spiral cam
- Heart-shaped cam

Follower

A follower is a rotating or an oscillating element of a machine that follows the motion of cam by direct contact.

If a cam moves in reciprocating motion the follower moves in vertically respect to the axis of the cam.

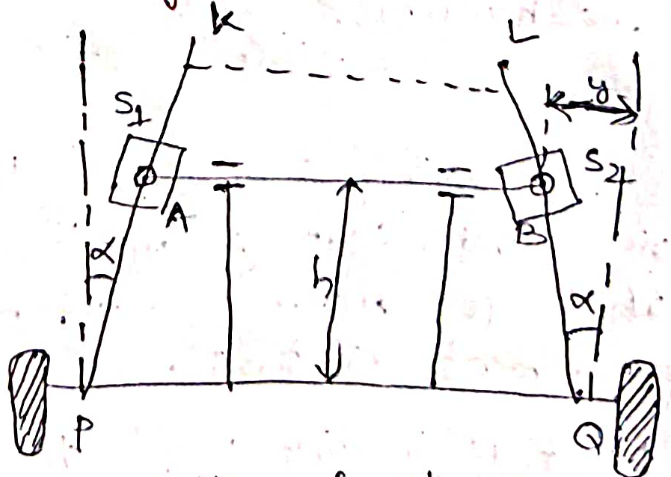
→ This part of the machine is mainly following the cam which can be reciprocating or oscillating in motion.

→ Types of follower :-

- knife edge follower
- Roller follower
- flat-faced follower
- spherical follower
- Radial follower
- Offset follower

2/ Explain briefly about Davis steering gear :-

Ans



This is the condition of straight motion of the ~~vehicle~~ vehicle, the gear is in the mid position with an equal inclination of the arm 'PK' & 'QL' making angle 'α' & distance 'y' from the slider & vertical.

In this position, $\tan\alpha = y/h$

h = vertical distance PQ & AB,

b = wheel base

Now, ~~tan θ~~ $\tan(\alpha - \theta) = \frac{y - x}{h}$

$$\frac{\tan\alpha - \tan\theta}{1 + \tan\alpha \tan\theta} = \frac{y - x}{h}$$

using, $\tan\alpha = y/h$

$$\tan\theta = \frac{hx}{y^2 - xy + h^2}$$

similarly, $\tan(\alpha + \phi) = \frac{y + x}{h}$

$$\tan\phi = \frac{hx}{y^2 + xy + h^2}$$

For correct steering:-

$$\cot\phi - \cot\theta = \frac{c}{b}$$

$$\frac{y^2 + xy + h^2}{hx} - \frac{y^2 - xy + h^2}{hx} = \frac{c}{b}$$

$$\frac{y}{h} = \frac{c}{2b} \Rightarrow \tan\alpha = \frac{c}{2b} \quad (\because \tan\alpha = \frac{y}{h}).$$

3/ Why a roller follower is preferred over a knife-edge follower ? state two advantages & applications of roller follower.

Ans

In case of knife edge follower there is sliding motion between the contacting surface of cam & follower.

Because of small contact area, there is excessive wear. Therefore it is not frequently used. Whereas in roller follower there is rolling motion between contacting surface & more contact area, therefore rate of wear is greatly reduced.

This is why a roller follower is always preferred over a knife-edge follower.

Advantages:-

(i) Less wear, more life

(ii) less side thrust as compared to knife edge follower.

Application:-

→ used in stationary oil.

→ Also used in gas engines.

4/. Explain about cam mechanisms in detail.

Ans The transformation of one of the simple motions, such as rotation, into any other motions is often conventionally accomplished by means of a cam mechanism.

A cam mechanism usually consists of 2 moving elements, the cam & the follower, mounted on a fixed frame. cam devices are versatile, and almost any arbitrarily-specified motion can be obtained.

→ A cam may be defined as a machine element having a curved outline or a curved groove, which by oscillation gives a predetermined specified motion to another element called follower.

The cam has a very important function in the operation of many classes of machines, especially those of the automatic type, such as printing presses, shoe machinery, textile machinery, gear-cutting machines and screw machines.

→ In any class of machinary in which automatic control & accurate timing are paramount.

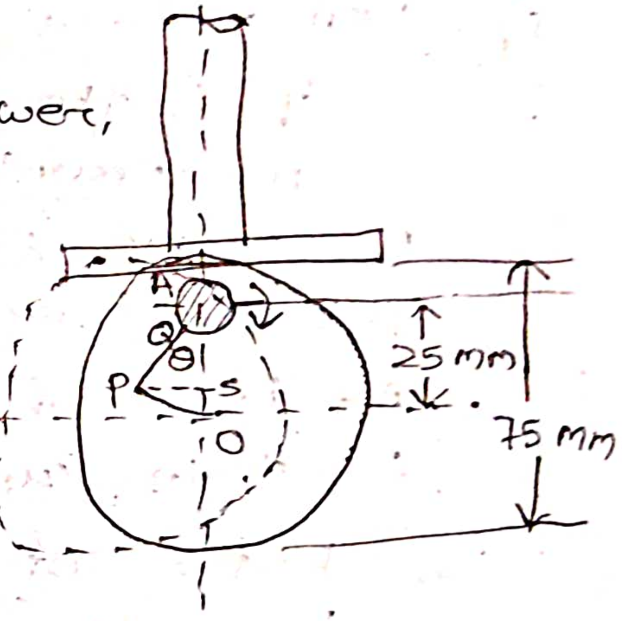
5/ A cam consists of circular disc of dia. 75 mm with its centre displaced 25 mm from axis. the follower has a flat surface in contact with cam & the line of action of follower is vertical & passes through shaft axis. Mass of follower is 2.3 kg & stiffness of 3.5 N/mm. In lowest position, the spring force is 45N. Derive an expression for the acc^n of follower in terms of angle of rotation from beginning of lift.

Sol^n Given $d = 75$ mm, so $r = 37.5$ mm

$m = 2.3$ kg ; displaced length $= 25$ mm (OQ)

$s = 3.5$ N/mm ; $S = 45$ N

From fig, displacement of follower,



$$x = AB = OS = OQ - QS$$
$$= OQ - PQ\cos\theta$$
$$= OQ - OQ\cos\theta$$
$$= OQ(1-\cos\theta) = 25(1-\cos\theta) \quad \text{—(i)}$$

Diff. eq^n (i) w.r.t. 't',

$$v = \frac{dx}{dt} = \frac{dx}{d\theta}\times\frac{d\theta}{dt} = \frac{dx}{d\theta}\times\omega$$

$$= 25\sin\theta\times\omega = 25\omega\sin\theta \quad \text{—(ii)}$$

Now, differenciating, eq^n (ii), w.r.t. 't',

$$a = \frac{dv}{dt} = \frac{dv}{d\theta}\times\frac{d\theta}{dt} = 25\omega\cos\theta\times\omega$$

$$= 25\omega^2\cos\theta \text{ mm/s}^2$$

$$= 0.025\omega^2\cos\theta \text{ m/s}^2$$

(Ans)

6/ What is turning moment diagram? Explain ~~all~~ the terms used in this equation.

Ans → It is otherwise called as torque crank angle diagram. Torque angle diagram is the graphical representation of crank per where the crank angle is taken in x-axis and torque angle in Y-axis.

→ Turning moment ~~is~~ given by,

$$T = F_p \left[\sin\theta + \frac{\sin 2\theta}{2(n^2 - \sin^2\theta)}\right] r$$

$F_p = P \times A$, where

'T' is the turning moment,

r = crank radius

F_p = piston effort

P = pressure in piston

A = Area of piston

θ = Angle rotated by the crankshaft

n = ratio of length of connecting rod to radius of crank = l/r

7/ Explain the working principle of a flywheel ~~with~~ & its uses.

Ans <u>Working principle of a flywheel:-</u>

The main working principle of a flywheel is based on rotational mass MOI, where the rotational kinetic energy is stored & released in the wheel, when the wheel store kinetic energy the rotational speed of wheel gets increases.

When the demand for high energy is required, the wheel releases its kinetic energy & the wheel's speed gets slower.

The kinetic energy stored on the flywheel depends on the mass MOI & the speed of flywheel. The energy stored in the flywheel is given by the eqⁿ,

$$\boxed{K.E. = \frac{1}{2} I \omega^2}$$

where, I = mass M.O.I.
ω = mean angular speed of the wheel.

As speed changes K.E. associated with flywheel also changes, the change in KE of the flywheel is given,

change in K.E. = K.E. at initial − K.E. at final

$$= \frac{1}{2} I \omega_i^2 - \frac{1}{2} I \omega_f^2$$

$$\therefore \Delta K.E. = \frac{1}{2} I \omega^2 \left[\frac{\omega_i - \omega_f}{\omega} \right]$$

where ω_i = Initial angular speed of ~~wheel~~ wheel
ω_f = Final angular speed of wheel

*Uses :- (i) In IC engines
(ii) In diesel generator
(iii) In punching & blanking operation etc.

Q/ Find the expression for fluctuation of speed.

Ans The difference betⁿ maxᵐ or minimum speed is known as fluctuation of speed.

workdone = $T \times \theta$

Excessive work = Area AB~~C~~EFG

Less of work = Area OIA, CDE, GHI

θ = Angle turn.

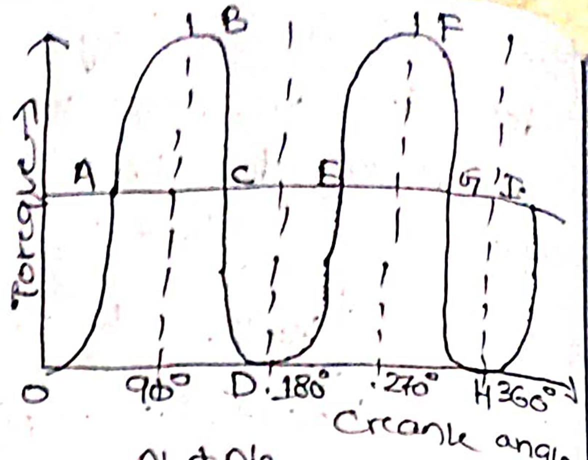
Terms used :-

N_1 = max^m speed of flywheel

N_2 = min. speed of flywheel

ω_1 = max^m angular velocity

ω_2 = min. angular velocity



mean speed is given by, $N = \frac{N_1 + N_2}{2}$

$$\omega = \frac{\omega_1 + \omega_2}{2}$$

I = mass MOI $(I) = mk^2 = mR^2$

ΔE = max^m fluctuation of speed

$$= \frac{1}{2} I\omega_1^2 - \frac{1}{2} I\omega_2^2 = \frac{1}{2} I (\omega_1^2 - \omega_2^2)$$

$$\Rightarrow \Delta E = \frac{1}{2} I \left[(\omega_1 + \omega_2)(\omega_1 - \omega_2) \right]$$

$$= I\omega (\omega_1 - \omega_2)$$

$$= \frac{I\omega (\omega_1 - \omega_2)\omega}{\omega} = I\omega^2 k_s$$

Where $\boxed{k_s = \frac{\omega_1 - \omega_2}{\omega}}$ (k_s is called co-efficient of fluctuation of speed)

Q/ The mass of flywheel of an engine is 6.5 tonnes & the radius of gyration is 1.8 meters. It's found from turning moment diagram that fluctuation of energy is 56 kN.m. If the mean speed of engine is 120 r.p.m., find the max^m & minimum speeds.

Sol^n Given $m = 6.5$ tonne

$m = 6500$ kg, $k = 1.8$ m

$\Delta E = 56$ kNm $= 56 \times 10^3$ Nm

& $N = 120$ r.p.m.

Let, N_1 & N_2 = max^m & min^m speeds respectively.

Now $\Delta E = 56 \times 10^3 = \frac{\pi^2}{900} \times m \cdot k^2 N (N_1 - N_2)$

$$= \frac{\pi^2}{900} \times 6500 (1.8)^2 \, 120 (N_1 - N_2)$$

$$= 27715 (N_1 - N_2)$$

$$N_1 - N_2 = \frac{56 \times 10^3}{27715} = 2 \text{ r.p.m.} \quad \text{——— (i)}$$

Now, mean speed, $(N) \Rightarrow 120 = \frac{N_1 + N_2}{N}$

or $N_1 + N_2 = 120 \times 2 = 240$ r.p.m. ——— (ii)

from eq^n (i) & (ii), $N_1 = 121$ r.p.m. & $N_2 = 119$ r.p.m.

10/ The turning moment curve for an engine is represented by eq^n, $T = 20000 + 9500 \sin 2\theta - 5700 \cos 2\theta)$ N.m, where 'θ' is the angle moved by crank from inner dead centre. If the resisting torque is constant, find the power developed by the engine.

Sol^n Given, $T = (20000 + 9500 \sin 2\theta - 5700 \cos 2\theta)$ N.m

$N = 180$ rpm $\Rightarrow \omega = 2\pi \times 180/60 = 18.85$ rad/sec.

$$C_s = \frac{\omega_1 - \omega_2}{\omega} = 1\% = 0.01$$

We know, workdone per revolution,

$$= \int_0^{2\pi} T\,d\theta = \int_0^{2\pi} (20000 + 9500 \sin 2\theta - 5700 \cos 2\theta)\,d\theta$$

$$= \left[20000 - \frac{9500 \cos 2\theta}{2} - \frac{5700 \sin 2\theta}{2}\right]_0^{2\pi}$$

$$= 20000 \times 2\pi = 40000\pi \text{ N.m.}$$

& mean resisting torque of the engine,

$$T_{mean} = \frac{\text{W.D. per revolution}}{2\pi}$$

$$= \frac{40000}{2\pi} = 20000 \text{ N.m}$$

$\therefore$ Power $= T_{Mean} \times \omega = 20000 \times 18.85$

$= 377000$ W

$= 377$ kW (Ans).